

# Measurement of Branching Fractions, and CP and Isospin Asymmetries, for $B \rightarrow K^* \gamma$

B. Aubert,<sup>1</sup> R. Barate,<sup>1</sup> D. Boutigny,<sup>1</sup> F. Couderc,<sup>1</sup> J.-M. Gaillard,<sup>1</sup> A. Hicheur,<sup>1</sup> Y. Karyotakis,<sup>1</sup> J. P. Lees,<sup>1</sup>  
V. Tisserand,<sup>1</sup> A. Zghiche,<sup>1</sup> A. Palano,<sup>2</sup> A. Pompili,<sup>2</sup> J. C. Chen,<sup>3</sup> N. D. Qi,<sup>3</sup> G. Rong,<sup>3</sup> P. Wang,<sup>3</sup> Y. S. Zhu,<sup>3</sup>  
G. Eigen,<sup>4</sup> I. Ofte,<sup>4</sup> B. Stugu,<sup>4</sup> G. S. Abrams,<sup>5</sup> A. W. Borgland,<sup>5</sup> A. B. Breon,<sup>5</sup> D. N. Brown,<sup>5</sup> J. Button-Shafer,<sup>5</sup>  
R. N. Cahn,<sup>5</sup> E. Charles,<sup>5</sup> C. T. Day,<sup>5</sup> M. S. Gill,<sup>5</sup> A. V. Gritsan,<sup>5</sup> Y. Groysman,<sup>5</sup> R. G. Jacobsen,<sup>5</sup> R. W. Kadel,<sup>5</sup>  
J. Kadyk,<sup>5</sup> L. T. Kerth,<sup>5</sup> Yu. G. Kolomensky,<sup>5</sup> G. Kukartsev,<sup>5</sup> G. Lynch,<sup>5</sup> L. M. Mir,<sup>5</sup> P. J. Oddone,<sup>5</sup>  
T. J. Orimoto,<sup>5</sup> M. Pripstein,<sup>5</sup> N. A. Roe,<sup>5</sup> M. T. Ronan,<sup>5</sup> V. G. Shelkov,<sup>5</sup> W. A. Wenzel,<sup>5</sup> M. Barrett,<sup>6</sup>  
K. E. Ford,<sup>6</sup> T. J. Harrison,<sup>6</sup> A. J. Hart,<sup>6</sup> C. M. Hawkes,<sup>6</sup> S. E. Morgan,<sup>6</sup> A. T. Watson,<sup>6</sup> M. Fritsch,<sup>7</sup> K. Goetzen,<sup>7</sup>  
T. Held,<sup>7</sup> H. Koch,<sup>7</sup> B. Lewandowski,<sup>7</sup> M. Pelizaeus,<sup>7</sup> M. Steinke,<sup>7</sup> J. T. Boyd,<sup>8</sup> N. Chevalier,<sup>8</sup> W. N. Cottingham,<sup>8</sup>  
M. P. Kelly,<sup>8</sup> T. E. Latham,<sup>8</sup> F. F. Wilson,<sup>8</sup> T. Cuhadar-Donszelmann,<sup>9</sup> C. Hearty,<sup>9</sup> N. S. Knecht,<sup>9</sup> T. S. Mattison,<sup>9</sup>  
J. A. McKenna,<sup>9</sup> D. Thiessen,<sup>9</sup> A. Khan,<sup>10</sup> P. Kyberd,<sup>10</sup> L. Teodorescu,<sup>10</sup> A. E. Blinov,<sup>11</sup> V. E. Blinov,<sup>11</sup>  
V. P. Druzhinin,<sup>11</sup> V. B. Golubev,<sup>11</sup> V. N. Ivanchenko,<sup>11</sup> E. A. Kravchenko,<sup>11</sup> A. P. Onuchin,<sup>11</sup> S. I. Serednyakov,<sup>11</sup>  
Yu. I. Skovpen,<sup>11</sup> E. P. Solodov,<sup>11</sup> A. N. Yushkov,<sup>11</sup> D. Best,<sup>12</sup> M. Bruinsma,<sup>12</sup> M. Chao,<sup>12</sup> I. Eschrich,<sup>12</sup>  
D. Kirkby,<sup>12</sup> A. J. Lankford,<sup>12</sup> M. Mandelkern,<sup>12</sup> R. K. Mommsen,<sup>12</sup> W. Roethel,<sup>12</sup> D. P. Stoker,<sup>12</sup> C. Buchanan,<sup>13</sup>  
B. L. Hartfiel,<sup>13</sup> S. D. Foulkes,<sup>14</sup> J. W. Gary,<sup>14</sup> B. C. Shen,<sup>14</sup> K. Wang,<sup>14</sup> D. del Re,<sup>15</sup> H. K. Hadavand,<sup>15</sup>  
E. J. Hill,<sup>15</sup> D. B. MacFarlane,<sup>15</sup> H. P. Paar,<sup>15</sup> Sh. Rahatlou,<sup>15</sup> V. Sharma,<sup>15</sup> J. W. Berryhill,<sup>16</sup> C. Campagnari,<sup>16</sup>  
B. Dahmes,<sup>16</sup> S. L. Levy,<sup>16</sup> O. Long,<sup>16</sup> A. Lu,<sup>16</sup> M. A. Mazur,<sup>16</sup> J. D. Richman,<sup>16</sup> W. Verkerke,<sup>16</sup> T. W. Beck,<sup>17</sup>  
A. M. Eisner,<sup>17</sup> C. A. Heusch,<sup>17</sup> W. S. Lockman,<sup>17</sup> G. Nesom,<sup>17</sup> T. Schalk,<sup>17</sup> R. E. Schmitz,<sup>17</sup> B. A. Schumm,<sup>17</sup>  
A. Seiden,<sup>17</sup> P. Spradlin,<sup>17</sup> D. C. Williams,<sup>17</sup> M. G. Wilson,<sup>17</sup> J. Albert,<sup>18</sup> E. Chen,<sup>18</sup> G. P. Dubois-Felsmann,<sup>18</sup>  
A. Dvoretzskii,<sup>18</sup> D. G. Hitlin,<sup>18</sup> I. Narsky,<sup>18</sup> T. Piatenko,<sup>18</sup> F. C. Porter,<sup>18</sup> A. Ryd,<sup>18</sup> A. Samuel,<sup>18</sup> S. Yang,<sup>18</sup>  
S. Jayatilke,<sup>19</sup> G. Mancinelli,<sup>19</sup> B. T. Meadows,<sup>19</sup> M. D. Sokoloff,<sup>19</sup> T. Abe,<sup>20</sup> F. Blanc,<sup>20</sup> P. Bloom,<sup>20</sup> S. Chen,<sup>20</sup>  
W. T. Ford,<sup>20</sup> U. Nauenberg,<sup>20</sup> A. Olivas,<sup>20</sup> P. Rankin,<sup>20</sup> J. G. Smith,<sup>20</sup> J. Zhang,<sup>20</sup> L. Zhang,<sup>20</sup> A. Chen,<sup>21</sup>  
J. L. Harton,<sup>21</sup> A. Soffer,<sup>21</sup> W. H. Toki,<sup>21</sup> R. J. Wilson,<sup>21</sup> Q. L. Zeng,<sup>21</sup> D. Altenburg,<sup>22</sup> T. Brandt,<sup>22</sup> J. Brose,<sup>22</sup>  
M. Dickopp,<sup>22</sup> E. Feltresi,<sup>22</sup> A. Hauke,<sup>22</sup> H. M. Lacker,<sup>22</sup> R. Müller-Pfefferkorn,<sup>22</sup> R. Nogowski,<sup>22</sup> S. Otto,<sup>22</sup>  
A. Petzold,<sup>22</sup> J. Schubert,<sup>22</sup> K. R. Schubert,<sup>22</sup> R. Schwierz,<sup>22</sup> B. Spaan,<sup>22</sup> J. E. Sundermann,<sup>22</sup> D. Bernard,<sup>23</sup>  
G. R. Bonneaud,<sup>23</sup> F. Brochard,<sup>23</sup> P. Grenier,<sup>23</sup> S. Schrenk,<sup>23</sup> Ch. Thiebaux,<sup>23</sup> G. Vasileiadis,<sup>23</sup> M. Verderi,<sup>23</sup>  
D. J. Bard,<sup>24</sup> P. J. Clark,<sup>24</sup> D. Lavin,<sup>24</sup> F. Muheim,<sup>24</sup> S. Playfer,<sup>24</sup> Y. Xie,<sup>24</sup> M. Andreotti,<sup>25</sup> V. Azzolini,<sup>25</sup>  
D. Bettoni,<sup>25</sup> C. Bozzi,<sup>25</sup> R. Calabrese,<sup>25</sup> G. Cibinetto,<sup>25</sup> E. Luppi,<sup>25</sup> M. Negrini,<sup>25</sup> L. Piemontese,<sup>25</sup> A. Sarti,<sup>25</sup>  
E. Treadwell,<sup>26</sup> R. Baldini-Ferroli,<sup>27</sup> A. Calcaterra,<sup>27</sup> R. de Sangro,<sup>27</sup> G. Finocchiaro,<sup>27</sup> P. Patteri,<sup>27</sup> M. Piccolo,<sup>27</sup>  
A. Zallo,<sup>27</sup> A. Buzzo,<sup>28</sup> R. Capra,<sup>28</sup> R. Contri,<sup>28</sup> G. Crosetti,<sup>28</sup> M. Lo Vetere,<sup>28</sup> M. Macri,<sup>28</sup> M. R. Monge,<sup>28</sup>  
S. Passaggio,<sup>28</sup> C. Patrignani,<sup>28</sup> E. Robutti,<sup>28</sup> A. Santroni,<sup>28</sup> S. Tosi,<sup>28</sup> S. Bailey,<sup>29</sup> G. Brandenburg,<sup>29</sup> M. Morii,<sup>29</sup>  
E. Won,<sup>29</sup> R. S. Dubitzky,<sup>30</sup> U. Langenegger,<sup>30</sup> W. Bhimji,<sup>31</sup> D. A. Bowerman,<sup>31</sup> P. D. Dauncey,<sup>31</sup> U. Egede,<sup>31</sup>  
J. R. Gaillard,<sup>31</sup> G. W. Morton,<sup>31</sup> J. A. Nash,<sup>31</sup> M. B. Nikolich,<sup>31</sup> G. P. Taylor,<sup>31</sup> M. J. Charles,<sup>32</sup> G. J. Grenier,<sup>32</sup>  
U. Mallik,<sup>32</sup> J. Cochran,<sup>33</sup> H. B. Crawley,<sup>33</sup> J. Lamsa,<sup>33</sup> W. T. Meyer,<sup>33</sup> S. Prell,<sup>33</sup> E. I. Rosenberg,<sup>33</sup> J. Yi,<sup>33</sup>  
M. Davier,<sup>34</sup> G. Grosdidier,<sup>34</sup> A. Höcker,<sup>34</sup> S. Laplace,<sup>34</sup> F. Le Diberder,<sup>34</sup> V. Lepeltier,<sup>34</sup> A. M. Lutz,<sup>34</sup>  
T. C. Petersen,<sup>34</sup> S. Plaszczynski,<sup>34</sup> M. H. Schune,<sup>34</sup> L. Tantot,<sup>34</sup> G. Wormser,<sup>34</sup> C. H. Cheng,<sup>35</sup> D. J. Lange,<sup>35</sup>  
M. C. Simani,<sup>35</sup> D. M. Wright,<sup>35</sup> A. J. Bevan,<sup>36</sup> C. A. Chavez,<sup>36</sup> J. P. Coleman,<sup>36</sup> I. J. Forster,<sup>36</sup> J. R. Fry,<sup>36</sup>  
E. Gabathuler,<sup>36</sup> R. Gamet,<sup>36</sup> R. J. Parry,<sup>36</sup> D. J. Payne,<sup>36</sup> R. J. Sloane,<sup>36</sup> C. Touramanis,<sup>36</sup> J. J. Back,<sup>37,\*</sup>  
C. M. Cormack,<sup>37</sup> P. F. Harrison,<sup>37,\*</sup> F. Di Lodovico,<sup>37</sup> G. B. Mohanty,<sup>37,\*</sup> C. L. Brown,<sup>38</sup> G. Cowan,<sup>38</sup>  
R. L. Flack,<sup>38</sup> H. U. Flaecher,<sup>38</sup> M. G. Green,<sup>38</sup> P. S. Jackson,<sup>38</sup> T. R. McMahon,<sup>38</sup> S. Ricciardi,<sup>38</sup> F. Salvatore,<sup>38</sup>  
M. A. Winter,<sup>38</sup> D. Brown,<sup>39</sup> C. L. Davis,<sup>39</sup> J. Allison,<sup>40</sup> N. R. Barlow,<sup>40</sup> R. J. Barlow,<sup>40</sup> M. C. Hodgkinson,<sup>40</sup>  
G. D. Lafferty,<sup>40</sup> A. J. Lyon,<sup>40</sup> J. C. Williams,<sup>40</sup> A. Farbin,<sup>41</sup> W. D. Hulsbergen,<sup>41</sup> A. Jawahery,<sup>41</sup> D. Kovalskyi,<sup>41</sup>  
C. K. Lae,<sup>41</sup> V. Lillard,<sup>41</sup> D. A. Roberts,<sup>41</sup> G. Blaylock,<sup>42</sup> C. Dallapiccola,<sup>42</sup> K. T. Flood,<sup>42</sup> S. S. Hertzbach,<sup>42</sup>  
K. Koeneke,<sup>42</sup> R. Kofler,<sup>42</sup> V. B. Koptchev,<sup>42</sup> T. B. Moore,<sup>42</sup> S. Saremi,<sup>42</sup> H. Staengle,<sup>42</sup> S. Willocq,<sup>42</sup> R. Cowan,<sup>43</sup>  
G. Sciolla,<sup>43</sup> F. Taylor,<sup>43</sup> R. K. Yamamoto,<sup>43</sup> D. J. J. Mangeol,<sup>44</sup> P. M. Patel,<sup>44</sup> S. H. Robertson,<sup>44</sup> A. Lazzaro,<sup>45</sup>  
F. Palombo,<sup>45</sup> J. M. Bauer,<sup>46</sup> L. Cremaldi,<sup>46</sup> V. Eschenburg,<sup>46</sup> R. Godang,<sup>46</sup> R. Kroeger,<sup>46</sup> J. Reidy,<sup>46</sup>  
D. A. Sanders,<sup>46</sup> D. J. Summers,<sup>46</sup> H. W. Zhao,<sup>46</sup> S. Brunet,<sup>47</sup> D. Côté,<sup>47</sup> P. Taras,<sup>47</sup> H. Nicholson,<sup>48</sup> F. Fabozzi,<sup>49,†</sup>

C. Gatto,<sup>49</sup> L. Lista,<sup>49</sup> D. Monorchio,<sup>49</sup> P. Paolucci,<sup>49</sup> D. Piccolo,<sup>49</sup> C. Sciacca,<sup>49</sup> M. Baak,<sup>50</sup> H. Bulten,<sup>50</sup> G. Raven,<sup>50</sup> H. L. Snoek,<sup>50</sup> L. Wilden,<sup>50</sup> C. P. Jessop,<sup>51</sup> J. M. LoSecco,<sup>51</sup> T. A. Gabriel,<sup>52</sup> T. Allmendinger,<sup>53</sup> B. Brau,<sup>53</sup> K. K. Gan,<sup>53</sup> K. Honscheid,<sup>53</sup> D. Hufnagel,<sup>53</sup> H. Kagan,<sup>53</sup> R. Kass,<sup>53</sup> T. Pulliam,<sup>53</sup> A. M. Rahimi,<sup>53</sup> R. Ter-Antonyan,<sup>53</sup> Q. K. Wong,<sup>53</sup> J. Brau,<sup>54</sup> R. Frey,<sup>54</sup> O. Igonkina,<sup>54</sup> C. T. Potter,<sup>54</sup> N. B. Sinev,<sup>54</sup> D. Strom,<sup>54</sup> E. Torrence,<sup>54</sup> F. Colecchia,<sup>55</sup> A. Dorigo,<sup>55</sup> F. Galeazzi,<sup>55</sup> M. Margoni,<sup>55</sup> M. Morandin,<sup>55</sup> M. Posocco,<sup>55</sup> M. Rotondo,<sup>55</sup> F. Simonetto,<sup>55</sup> R. Stroili,<sup>55</sup> G. Tiozzo,<sup>55</sup> C. Voci,<sup>55</sup> M. Benayoun,<sup>56</sup> H. Briand,<sup>56</sup> J. Chauveau,<sup>56</sup> P. David,<sup>56</sup> Ch. de la Vaissière,<sup>56</sup> L. Del Buono,<sup>56</sup> O. Hamon,<sup>56</sup> M. J. J. John,<sup>56</sup> Ph. Leruste,<sup>56</sup> J. Malcles,<sup>56</sup> J. Ocariz,<sup>56</sup> M. Pivk,<sup>56</sup> L. Roos,<sup>56</sup> S. T'Jampens,<sup>56</sup> G. Therin,<sup>56</sup> P. F. Manfredi,<sup>57</sup> V. Re,<sup>57</sup> P. K. Behera,<sup>58</sup> L. Gladney,<sup>58</sup> Q. H. Guo,<sup>58</sup> J. Panetta,<sup>58</sup> F. Anulli,<sup>27, 59</sup> M. Biasini,<sup>59</sup> I. M. Peruzzi,<sup>27, 59</sup> M. Pioppi,<sup>59</sup> C. Angelini,<sup>60</sup> G. Batignani,<sup>60</sup> S. Bettarini,<sup>60</sup> M. Bondioli,<sup>60</sup> F. Bucci,<sup>60</sup> G. Calderini,<sup>60</sup> M. Carpinelli,<sup>60</sup> F. Forti,<sup>60</sup> M. A. Giorgi,<sup>60</sup> A. Lusiani,<sup>60</sup> G. Marchiori,<sup>60</sup> F. Martinez-Vidal,<sup>60, ‡</sup> M. Morganti,<sup>60</sup> N. Neri,<sup>60</sup> E. Paoloni,<sup>60</sup> M. Rama,<sup>60</sup> G. Rizzo,<sup>60</sup> F. Sandrelli,<sup>60</sup> J. Walsh,<sup>60</sup> M. Haire,<sup>61</sup> D. Judd,<sup>61</sup> K. Paick,<sup>61</sup> D. E. Wagoner,<sup>61</sup> N. Danielson,<sup>62</sup> P. Elmer,<sup>62</sup> Y. P. Lau,<sup>62</sup> C. Lu,<sup>62</sup> V. Miftakov,<sup>62</sup> J. Olsen,<sup>62</sup> A. J. S. Smith,<sup>62</sup> A. V. Telnov,<sup>62</sup> F. Bellini,<sup>63</sup> G. Cavoto,<sup>62, 63</sup> R. Faccini,<sup>63</sup> F. Ferrarotto,<sup>63</sup> F. Ferroni,<sup>63</sup> M. Gaspero,<sup>63</sup> L. Li Gioi,<sup>63</sup> M. A. Mazzoni,<sup>63</sup> S. Morganti,<sup>63</sup> M. Pierini,<sup>63</sup> G. Piredda,<sup>63</sup> F. Safai Tehrani,<sup>63</sup> C. Voena,<sup>63</sup> S. Christ,<sup>64</sup> G. Wagner,<sup>64</sup> R. Waldi,<sup>64</sup> T. Adye,<sup>65</sup> N. De Groot,<sup>65</sup> B. Franek,<sup>65</sup> N. I. Geddes,<sup>65</sup> G. P. Gopal,<sup>65</sup> E. O. Olaiya,<sup>65</sup> R. Aleksan,<sup>66</sup> S. Emery,<sup>66</sup> A. Gaidot,<sup>66</sup> S. F. Ganzhur,<sup>66</sup> P.-F. Giraud,<sup>66</sup> G. Hamel de Monchenault,<sup>66</sup> W. Kozanecki,<sup>66</sup> M. Langer,<sup>66</sup> M. Legendre,<sup>66</sup> G. W. London,<sup>66</sup> B. Mayer,<sup>66</sup> G. Schott,<sup>66</sup> G. Vasseur,<sup>66</sup> Ch. Yèche,<sup>66</sup> M. Zito,<sup>66</sup> M. V. Purohit,<sup>67</sup> A. W. Weidemann,<sup>67</sup> J. R. Wilson,<sup>67</sup> F. X. Yumiceva,<sup>67</sup> D. Aston,<sup>68</sup> R. Bartoldus,<sup>68</sup> N. Berger,<sup>68</sup> A. M. Boyarski,<sup>68</sup> O. L. Buchmueller,<sup>68</sup> R. Claus,<sup>68</sup> M. R. Convery,<sup>68</sup> M. Cristinziani,<sup>68</sup> G. De Nardo,<sup>68</sup> D. Dong,<sup>68</sup> J. Dorfan,<sup>68</sup> D. Dujmic,<sup>68</sup> W. Dunwoodie,<sup>68</sup> E. E. Elsen,<sup>68</sup> S. Fan,<sup>68</sup> R. C. Field,<sup>68</sup> T. Glanzman,<sup>68</sup> S. J. Gowdy,<sup>68</sup> T. Hadig,<sup>68</sup> V. Halyo,<sup>68</sup> C. Hast,<sup>68</sup> T. Hryn'ova,<sup>68</sup> W. R. Innes,<sup>68</sup> M. H. Kelsey,<sup>68</sup> P. Kim,<sup>68</sup> M. L. Kocian,<sup>68</sup> D. W. G. S. Leith,<sup>68</sup> J. Libby,<sup>68</sup> S. Luitz,<sup>68</sup> V. Luth,<sup>68</sup> H. L. Lynch,<sup>68</sup> H. Marsiske,<sup>68</sup> R. Messner,<sup>68</sup> D. R. Muller,<sup>68</sup> C. P. O'Grady,<sup>68</sup> V. E. Ozcan,<sup>68</sup> A. Perazzo,<sup>68</sup> M. Perl,<sup>68</sup> S. Petrak,<sup>68</sup> B. N. Ratcliff,<sup>68</sup> A. Roodman,<sup>68</sup> A. A. Salnikov,<sup>68</sup> R. H. Schindler,<sup>68</sup> J. Schwiening,<sup>68</sup> G. Simi,<sup>68</sup> A. Snyder,<sup>68</sup> A. Soha,<sup>68</sup> J. Stelzer,<sup>68</sup> D. Su,<sup>68</sup> M. K. Sullivan,<sup>68</sup> J. Va'vra,<sup>68</sup> S. R. Wagner,<sup>68</sup> M. Weaver,<sup>68</sup> A. J. R. Weinstein,<sup>68</sup> W. J. Wisniewski,<sup>68</sup> M. Wittgen,<sup>68</sup> D. H. Wright,<sup>68</sup> A. K. Yarritu,<sup>68</sup> C. C. Young,<sup>68</sup> P. R. Burchat,<sup>69</sup> A. J. Edwards,<sup>69</sup> T. I. Meyer,<sup>69</sup> B. A. Petersen,<sup>69</sup> C. Roat,<sup>69</sup> S. Ahmed,<sup>70</sup> M. S. Alam,<sup>70</sup> J. A. Ernst,<sup>70</sup> M. A. Saeed,<sup>70</sup> M. Saleem,<sup>70</sup> F. R. Wappler,<sup>70</sup> W. Bugg,<sup>71</sup> M. Krishnamurthy,<sup>71</sup> S. M. Spanier,<sup>71</sup> R. Eckmann,<sup>72</sup> H. Kim,<sup>72</sup> J. L. Ritchie,<sup>72</sup> A. Satpathy,<sup>72</sup> R. F. Schwitters,<sup>72</sup> J. M. Izen,<sup>73</sup> I. Kitayama,<sup>73</sup> X. C. Lou,<sup>73</sup> S. Ye,<sup>73</sup> F. Bianchi,<sup>74</sup> M. Bona,<sup>74</sup> F. Gallo,<sup>74</sup> D. Gamba,<sup>74</sup> C. Borean,<sup>75</sup> L. Bosisio,<sup>75</sup> C. Cartaro,<sup>75</sup> F. Cossutti,<sup>75</sup> G. Della Ricca,<sup>75</sup> S. Dittongo,<sup>75</sup> S. Grancagnolo,<sup>75</sup> L. Lanceri,<sup>75</sup> P. Poropat,<sup>75, §</sup> L. Vitale,<sup>75</sup> G. Vuagnin,<sup>75</sup> R. S. Panvini,<sup>76</sup> Sw. Banerjee,<sup>77</sup> C. M. Brown,<sup>77</sup> D. Fortin,<sup>77</sup> P. D. Jackson,<sup>77</sup> R. Kowalewski,<sup>77</sup> J. M. Roney,<sup>77</sup> R. J. Sobie,<sup>77</sup> H. R. Band,<sup>78</sup> S. Dasu,<sup>78</sup> M. Datta,<sup>78</sup> A. M. Eichenbaum,<sup>78</sup> M. Graham,<sup>78</sup> J. J. Hollar,<sup>78</sup> J. R. Johnson,<sup>78</sup> P. E. Kutter,<sup>78</sup> H. Li,<sup>78</sup> R. Liu,<sup>78</sup> A. Mihalyi,<sup>78</sup> A. K. Mohapatra,<sup>78</sup> Y. Pan,<sup>78</sup> R. Prepost,<sup>78</sup> A. E. Rubin,<sup>78</sup> S. J. Sekula,<sup>78</sup> P. Tan,<sup>78</sup> J. H. von Wimmersperg-Toeller,<sup>78</sup> J. Wu,<sup>78</sup> S. L. Wu,<sup>78</sup> Z. Yu,<sup>78</sup> M. G. Greene,<sup>79</sup> and H. Neal<sup>79</sup>

(The BABAR Collaboration)

<sup>1</sup>Laboratoire de Physique des Particules, F-74941 Annecy-le-Vieux, France

<sup>2</sup>Università di Bari, Dipartimento di Fisica and INFN, I-70126 Bari, Italy

<sup>3</sup>Institute of High Energy Physics, Beijing 100039, China

<sup>4</sup>University of Bergen, Inst. of Physics, N-5007 Bergen, Norway

<sup>5</sup>Lawrence Berkeley National Laboratory and University of California, Berkeley, CA 94720, USA

<sup>6</sup>University of Birmingham, Birmingham, B15 2TT, United Kingdom

<sup>7</sup>Ruhr Universität Bochum, Institut für Experimentalphysik 1, D-44780 Bochum, Germany

<sup>8</sup>University of Bristol, Bristol BS8 1TL, United Kingdom

<sup>9</sup>University of British Columbia, Vancouver, BC, Canada V6T 1Z1

<sup>10</sup>Brunel University, Uxbridge, Middlesex UB8 3PH, United Kingdom

<sup>11</sup>Budker Institute of Nuclear Physics, Novosibirsk 630090, Russia

<sup>12</sup>University of California at Irvine, Irvine, CA 92697, USA

<sup>13</sup>University of California at Los Angeles, Los Angeles, CA 90024, USA

<sup>14</sup>University of California at Riverside, Riverside, CA 92521, USA

<sup>15</sup>University of California at San Diego, La Jolla, CA 92093, USA

<sup>16</sup>University of California at Santa Barbara, Santa Barbara, CA 93106, USA

<sup>17</sup>University of California at Santa Cruz, Institute for Particle Physics, Santa Cruz, CA 95064, USA

<sup>18</sup>California Institute of Technology, Pasadena, CA 91125, USA

- <sup>19</sup>University of Cincinnati, Cincinnati, OH 45221, USA
- <sup>20</sup>University of Colorado, Boulder, CO 80309, USA
- <sup>21</sup>Colorado State University, Fort Collins, CO 80523, USA
- <sup>22</sup>Technische Universität Dresden, Institut für Kern- und Teilchenphysik, D-01062 Dresden, Germany
- <sup>23</sup>Ecole Polytechnique, LLR, F-91128 Palaiseau, France
- <sup>24</sup>University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom
- <sup>25</sup>Università di Ferrara, Dipartimento di Fisica and INFN, I-44100 Ferrara, Italy
- <sup>26</sup>Florida A&M University, Tallahassee, FL 32307, USA
- <sup>27</sup>Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy
- <sup>28</sup>Università di Genova, Dipartimento di Fisica and INFN, I-16146 Genova, Italy
- <sup>29</sup>Harvard University, Cambridge, MA 02138, USA
- <sup>30</sup>Universität Heidelberg, Physikalisches Institut, Philosophenweg 12, D-69120 Heidelberg, Germany
- <sup>31</sup>Imperial College London, London, SW7 2AZ, United Kingdom
- <sup>32</sup>University of Iowa, Iowa City, IA 52242, USA
- <sup>33</sup>Iowa State University, Ames, IA 50011-3160, USA
- <sup>34</sup>Laboratoire de l'Accélérateur Linéaire, F-91898 Orsay, France
- <sup>35</sup>Lawrence Livermore National Laboratory, Livermore, CA 94550, USA
- <sup>36</sup>University of Liverpool, Liverpool L69 7ZE, United Kingdom
- <sup>37</sup>Queen Mary, University of London, E1 4NS, United Kingdom
- <sup>38</sup>University of London, Royal Holloway and Bedford New College, Egham, Surrey TW20 0EX, United Kingdom
- <sup>39</sup>University of Louisville, Louisville, KY 40292, USA
- <sup>40</sup>University of Manchester, Manchester M13 9PL, United Kingdom
- <sup>41</sup>University of Maryland, College Park, MD 20742, USA
- <sup>42</sup>University of Massachusetts, Amherst, MA 01003, USA
- <sup>43</sup>Massachusetts Institute of Technology, Laboratory for Nuclear Science, Cambridge, MA 02139, USA
- <sup>44</sup>McGill University, Montréal, QC, Canada H3A 2T8
- <sup>45</sup>Università di Milano, Dipartimento di Fisica and INFN, I-20133 Milano, Italy
- <sup>46</sup>University of Mississippi, University, MS 38677, USA
- <sup>47</sup>Université de Montréal, Laboratoire René J. A. Lévesque, Montréal, QC, Canada H3C 3J7
- <sup>48</sup>Mount Holyoke College, South Hadley, MA 01075, USA
- <sup>49</sup>Università di Napoli Federico II, Dipartimento di Scienze Fisiche and INFN, I-80126, Napoli, Italy
- <sup>50</sup>NIKHEF, National Institute for Nuclear Physics and High Energy Physics, NL-1009 DB Amsterdam, The Netherlands
- <sup>51</sup>University of Notre Dame, Notre Dame, IN 46556, USA
- <sup>52</sup>Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA
- <sup>53</sup>Ohio State University, Columbus, OH 43210, USA
- <sup>54</sup>University of Oregon, Eugene, OR 97403, USA
- <sup>55</sup>Università di Padova, Dipartimento di Fisica and INFN, I-35131 Padova, Italy
- <sup>56</sup>Universités Paris VI et VII, Laboratoire de Physique Nucléaire et de Hautes Energies, F-75252 Paris, France
- <sup>57</sup>Università di Pavia, Dipartimento di Elettronica and INFN, I-27100 Pavia, Italy
- <sup>58</sup>University of Pennsylvania, Philadelphia, PA 19104, USA
- <sup>59</sup>Università di Perugia, Dipartimento di Fisica and INFN, I-06100 Perugia, Italy
- <sup>60</sup>Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy
- <sup>61</sup>Prairie View A&M University, Prairie View, TX 77446, USA
- <sup>62</sup>Princeton University, Princeton, NJ 08544, USA
- <sup>63</sup>Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy
- <sup>64</sup>Universität Rostock, D-18051 Rostock, Germany
- <sup>65</sup>Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, United Kingdom
- <sup>66</sup>DSM/Dapnia, CEA/Saclay, F-91191 Gif-sur-Yvette, France
- <sup>67</sup>University of South Carolina, Columbia, SC 29208, USA
- <sup>68</sup>Stanford Linear Accelerator Center, Stanford, CA 94309, USA
- <sup>69</sup>Stanford University, Stanford, CA 94305-4060, USA
- <sup>70</sup>State Univ. of New York, Albany, NY 12222, USA
- <sup>71</sup>University of Tennessee, Knoxville, TN 37996, USA
- <sup>72</sup>University of Texas at Austin, Austin, TX 78712, USA
- <sup>73</sup>University of Texas at Dallas, Richardson, TX 75083, USA
- <sup>74</sup>Università di Torino, Dipartimento di Fisica Sperimentale and INFN, I-10125 Torino, Italy
- <sup>75</sup>Università di Trieste, Dipartimento di Fisica and INFN, I-34127 Trieste, Italy
- <sup>76</sup>Vanderbilt University, Nashville, TN 37235, USA
- <sup>77</sup>University of Victoria, Victoria, BC, Canada V8W 3P6
- <sup>78</sup>University of Wisconsin, Madison, WI 53706, USA
- <sup>79</sup>Yale University, New Haven, CT 06511, USA

The branching fractions of the decays  $B^0 \rightarrow K^{*0}\gamma$  and  $B^+ \rightarrow K^{*+}\gamma$  are measured using a sample of  $88 \times 10^6 B\bar{B}$  events collected with the BABAR detector at the PEP-II asymmetric-energy  $e^+e^-$

collider. We find  $\mathcal{B}(B^0 \rightarrow K^{*0}\gamma) = (3.92 \pm 0.20(\text{stat.}) \pm 0.24(\text{syst.})) \times 10^{-5}$ ,  $\mathcal{B}(B^+ \rightarrow K^{*+}\gamma) = (3.87 \pm 0.28(\text{stat.}) \pm 0.26(\text{syst.})) \times 10^{-5}$ . Our measurements also constrain the direct  $CP$  asymmetry to be  $-0.074 < \mathcal{A}(B \rightarrow K^*\gamma) < 0.049$  and the isospin asymmetry to be  $-0.046 < \Delta_{0-} < 0.146$ , both at the 90% confidence level.

PACS numbers: 13.25.Hw, 12.15.Hh, 11.30.Er

Within the Standard Model (SM), the decays  $B \rightarrow K^*\gamma$  proceed dominantly through one-loop  $b \rightarrow s\gamma$  electromagnetic “penguin” transitions [1]. Non-SM virtual particles may be present in these loops, changing the decay rates from the SM predictions. Theoretical calculations of exclusive  $B \rightarrow K^*\gamma$  decay rates have large uncertainties due to nonperturbative hadronic effects [2, 3, 4], limiting their usefulness for probing new physics. Previous measurements [5, 6, 7] of the branching fractions are already more precise than SM-based theoretical estimates, and are in reasonable agreement with them. Calculations [8, 9] of the form factor for  $B \rightarrow K^*\gamma$  can be tested using improved measurements of these branching fractions.

Much of the theoretical uncertainty in the branching fractions cancels in the ratios defining the isospin asymmetry  $\Delta_{0-}$  and the  $CP$  asymmetry  $\mathcal{A}$ :

$$\Delta_{0-} = \frac{\Gamma(\bar{B}^0 \rightarrow \bar{K}^{*0}\gamma) - \Gamma(B^- \rightarrow K^{*-}\gamma)}{\Gamma(\bar{B}^0 \rightarrow \bar{K}^{*0}\gamma) + \Gamma(B^- \rightarrow K^{*-}\gamma)}, \quad (1)$$

$$\mathcal{A} = \frac{\Gamma(\bar{B} \rightarrow \bar{K}^*\gamma) - \Gamma(B \rightarrow K^*\gamma)}{\Gamma(\bar{B} \rightarrow \bar{K}^*\gamma) + \Gamma(B \rightarrow K^*\gamma)}, \quad (2)$$

making them stringent tests of the SM. A further advantage of these asymmetries is that some experimental systematic uncertainties cancel in the ratios. The SM predicts a positive value of  $\Delta_{0-}$  between 5 and 10% [10], and  $|\mathcal{A}|$  less than 1% [11]. New physics contributions can modify these values significantly [10, 11].

In this Letter, we present measurements of the exclusive branching fractions  $\mathcal{B}(B^0 \rightarrow K^{*0}\gamma)$  and  $\mathcal{B}(B^+ \rightarrow K^{*+}\gamma)$ , the isospin asymmetry ( $\Delta_{0-}$ ), and the  $CP$  asymmetries  $\mathcal{A}(B^0 \rightarrow K^{*0}\gamma)$  and  $\mathcal{A}(B^+ \rightarrow K^{*+}\gamma)$ .  $K^*$  refers to the  $K^*(892)$  resonance throughout this paper. Inclusion of charge-conjugate decays is implied except in the definitions of  $\mathcal{A}$ . This analysis uses  $(88 \pm 1) \times 10^6 B\bar{B}$  events, from  $\Upsilon(4S)$  decays, recorded by the *BABAR* detector [12]. An additional  $10 \text{ fb}^{-1}$  of data, taken 40 MeV below the  $\Upsilon(4S)$  resonance, is used for studying non- $B$  continuum background. After  $B \rightarrow K^*\gamma$  event reconstruction and background rejection, multi-dimensional extended maximum likelihood fits are used to extract the final results.

We reconstruct  $B^0 \rightarrow K^{*0}\gamma$  in the  $K^{*0} \rightarrow K^+\pi^-$ ,  $K_s^0\pi^0$  modes and  $B^+ \rightarrow K^{*+}\gamma$  in the  $K^{*+} \rightarrow K^+\pi^0$ ,  $K_s^0\pi^+$  modes as described in detail in Ref. [6, 12]. Reconstructed tracks are identified as final state  $\pi^\pm$  and

$K^\pm$  mesons by measuring the angle of the Cherenkov cone and energy loss along the track ( $dE/dx$ ). The  $K_s^0$  candidates are composed from pairs of oppositely charged tracks with an invariant mass that is within  $3.3\sigma$  of the nominal  $K_s^0$  mass and with a vertex that is at least 0.3 cm away from the primary event vertex. The  $\pi^0$ -candidate momentum vector is determined by a mass-constrained fit to pairs of photons, reconstructed from energy deposits in the calorimeter that are not matched to tracks. The  $K$  and  $\pi$  candidates are combined to form  $K^*$  candidates, which are required to have invariant mass in the range  $800 < M_{K\pi} < 1000 \text{ MeV}/c^2$ . The primary-photon candidates are required to have high center-of-mass (CM) energy, between 1.5 and 3.5 GeV, and to satisfy additional requirements designed to suppress the large  $\pi^0$  and  $\eta$  background as described in Ref. [6].

The  $B$ -meson candidates are reconstructed by combining the  $K^*$  and high-energy photon candidates. We define in the CM frame (denoted by asterisks)  $\Delta E^* \equiv E_B^* - E_{\text{beam}}^*$ , where  $E_{\text{beam}}^*$  is the beam energy, known to high precision, and  $E_B^* = E_\gamma^* + E_{K^*}^*$  is the energy of the  $B$ -meson candidate. We also define the beam-energy-substituted mass  $m_{\text{ES}} \equiv \sqrt{E_{\text{beam}}^{*2} - p_B'^{*2}}$ , where  $p_B'^*$  is the momentum of the  $B$  candidate modified by scaling the photon energy to make  $E_\gamma^* + E_{K^*}^* - E_{\text{beam}}^* = 0$ . This procedure reduces the tail in the signal  $m_{\text{ES}}$  distribution, which results from the asymmetric calorimeter response. For signal decays, this “rescaled”  $m_{\text{ES}}$  peaks near  $5.279 \text{ GeV}/c^2$  with a resolution of  $\approx 3 \text{ MeV}/c^2$  and  $\Delta E^*$  peaks near 0 MeV with a resolution of  $\approx 50 \text{ MeV}$ . We consider only candidates with  $m_{\text{ES}} > 5.20 \text{ GeV}/c^2$  and  $|\Delta E^*| < 0.3 \text{ GeV}$ .

Background events arise predominantly from random combinations of particles in  $q\bar{q}$  production ( $q=u,d,s,c$ ), with the high-energy photon originating from initial-state radiation or from  $\pi^0$  and  $\eta$  decays. We suppress this jet-like background in favor of the spherical signal events, using several event-shape variables as in Ref. [6]. To maximize separation between signal and background, these variables are combined in neural networks that are separately optimized for each decay mode. Each network is trained using Monte Carlo (MC) events, and is validated on statistically independent MC samples. Cuts are made on the neural-network output to suppress continuum background. The  $m_{\text{ES}}$  and  $\Delta E^*$  distributions of data are shown in Fig. 1 for all four  $K^*$  decay modes.

The remaining background includes that from  $B\bar{B}$  events, which is dominated by  $B \rightarrow X_s\gamma$  decays, where  $X_s$  represents hadronic final states other than  $K^*$ . If one

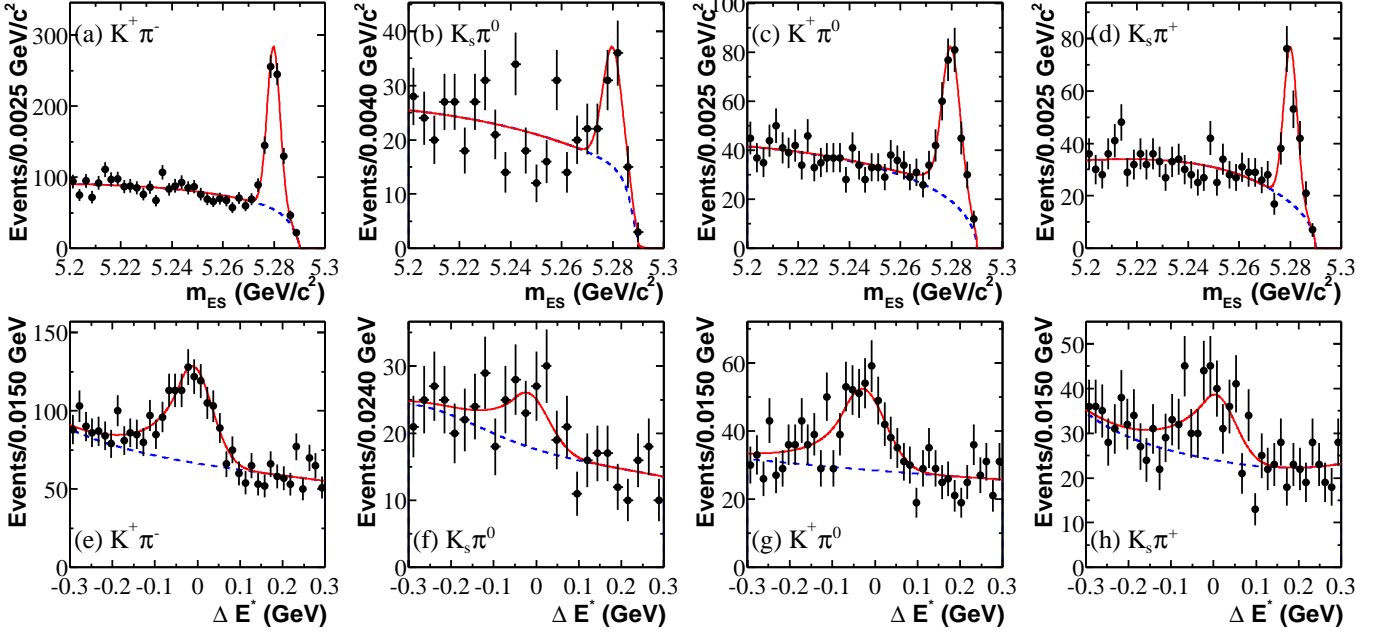


FIG. 1:  $m_{ES}$  and  $\Delta E^*$  distributions for the  $B \rightarrow K^* \gamma$  candidates. The points are data, and the solid and dashed curves show the projections of the complete fit and the background component alone, respectively. The fits used to extract the signal yields are described in the text.

TABLE I: The signal efficiency  $\epsilon$ , the fitted signal yield  $N_S$ , the branching fraction  $\mathcal{B}$ , and the CP-asymmetry  $\mathcal{A}$  for each decay mode. The combined branching fractions and CP-asymmetries for  $B^0 \rightarrow K^{*0} \gamma$  and for  $B^+ \rightarrow K^{*+} \gamma$  are also shown. Errors are statistical and systematic, with the exception of  $\epsilon$  and  $N_S$ , which have only systematic and statistical errors respectively. The detailed systematic errors are listed in Table II.

| Mode       | $\epsilon(\%)$ | $N_S$       | $\mathcal{B}(\times 10^{-5})$ | Combined $\mathcal{B}(\times 10^{-5})$ | $\mathcal{A}$              | Combined $\mathcal{A}$     |
|------------|----------------|-------------|-------------------------------|----------------------------------------|----------------------------|----------------------------|
| $K^+\pi^-$ | $24.4\pm 1.4$  | $583\pm 30$ | $3.92\pm 0.20\pm 0.23$        | $3.92\pm 0.20\pm 0.24$                 | $-0.069\pm 0.046\pm 0.011$ | $-0.013\pm 0.036\pm 0.010$ |
| $K_s\pi^0$ | $15.3\pm 1.9$  | $62\pm 15$  | $4.02\pm 0.99\pm 0.51$        |                                        |                            |                            |
| $K^+\pi^0$ | $17.4\pm 1.6$  | $251\pm 23$ | $4.90\pm 0.45\pm 0.46$        | $3.87\pm 0.28\pm 0.26$                 | $0.084\pm 0.075\pm 0.007$  |                            |
| $K_s\pi^+$ | $22.1\pm 1.4$  | $157\pm 16$ | $3.52\pm 0.35\pm 0.22$        |                                        | $0.061\pm 0.092\pm 0.007$  |                            |

or more particles escape detection,  $X_s$  may be incorrectly reconstructed as  $K^*$ , leading to a value of  $m_{ES}$  near the B meson mass, but with  $\Delta E^*$  distinctly negative.

For each decay mode, the signal yield and asymmetry  $\mathcal{A}$  (except for the  $K_s \pi^0$  mode) are simultaneously extracted using an extended unbinned maximum likelihood fit,

$$\mathcal{L} = \exp\left(-\sum_{i=1}^3 n_i\right) \cdot \left[\prod_{j=1}^N \sum_{i=1}^3 N_i \mathcal{P}(\vec{x}_j; \vec{\alpha}_i)\right],$$

to the two-dimensional distribution of  $m_{ES}$  and  $\Delta E^*$  with three hypotheses (index  $i$ ): signal, continuum background, and  $B$  background. The probability density function (PDF)  $\mathcal{P}(\vec{x}_j; \vec{\alpha}_i)$  for each of the three hypotheses is the product of individual PDFs of the fit variables  $\vec{x}_j = (m_{ES}, \Delta E^*)$ .  $\vec{\alpha}_i$  are the shape parameters for the PDFs described below. In the three self-flavor-tagged modes ( $K^+ \pi^-$ ,  $K^+ \pi^0$ , and  $K_s \pi^+$ ),  $N_i = \frac{1}{2}(1 - \mathcal{F}\mathcal{A}_i)n_i$ ,

where  $n_i$  and  $\mathcal{A}_i$  stand for the total yield and CP-asymmetry of signal, continuum background, and  $B$  background, while in the  $K_s \pi^0$  decay mode,  $N_i = n_i$ . The bottom-quark flavor,  $\mathcal{F}$ , is defined as  $-1$  for  $b$  quarks and  $+1$  for  $\bar{b}$  quarks. In the  $K^+ \pi^-$  mode, mistagging is possible if both the pion and kaon are misidentified, but this probability is negligibly small. We assume that the CP asymmetry of the  $B$  background and that of the continuum background are the same.

To reduce systematic errors, most of the fit parameters for the signal and for the continuum background are determined by a fit to data. For continuum background, the  $\Delta E^*$  distribution is modeled by a first-order polynomial function with the exception of  $K_s \pi^+$ , where a second-order polynomial is used. The  $m_{ES}$  distribution for continuum background is modeled with an ARGUS function [14]. In the  $K^+ \pi^0$  decay mode, the continuum background shape is simultaneously fit to the off-resonance data to obtain a stabler fit. For the  $B$  background, the

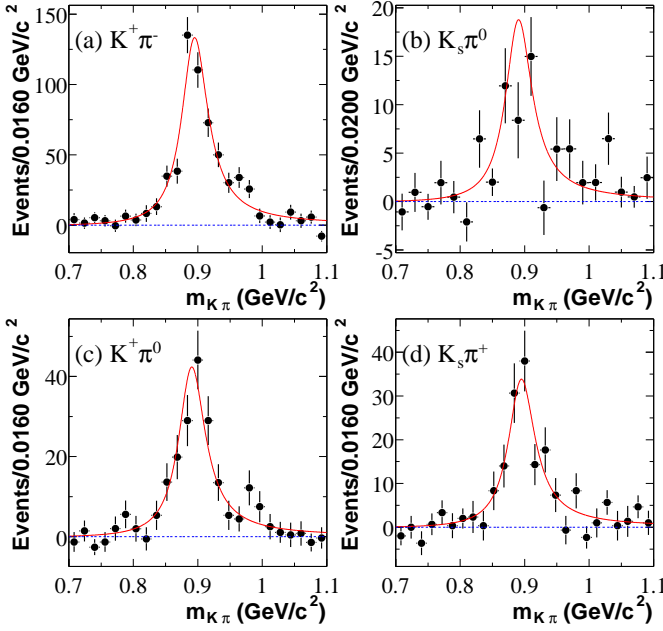


FIG. 2:  $m_{K\pi}$  spectra for the different decay modes for events in the signal region after background subtraction using sidebands in  $m_{ES}$  and  $\Delta E^*$ . The points are data and solid curves represent relativistic p-wave Breit-Wigner line shapes with masses and widths of  $K^*$  taken from Ref. [13].

Gaussian distribution used for  $\Delta E^*$  and the Novosibirsk function [15] used for  $m_{ES}$  have all shape parameters fixed to values determined from MC. The signal  $\Delta E^*$  distribution is modeled as a Crystal Ball function [16], which is a Gaussian distribution with a low-side power-law tail that is fixed using MC. The  $m_{ES}$  distribution for signal is modeled as a Gaussian function, except for the  $K^+\pi^0$  decay mode, where a Crystal Ball function, with tail parameters fixed using MC fits, is used to accommodate a low-side tail due to the  $\pi^0$  energy lost from the calorimeter. The same low-side tail in the  $K_s^0\pi^0$  decay mode is ignored due to the small number of events in this mode.

Correlations between  $m_{ES}$  and  $\Delta E^*$  distributions could introduce a bias in the signal yields. To study this, randomly selected events from our detailed MC simulation of the signal were mixed with background events generated using the PDF from the fit. In this way we determined that the  $K^+\pi^-$  efficiency must be corrected by multiplying it by 0.98. For the  $K_s^0\pi^0$ ,  $K^+\pi^0$ , and  $K_s^0\pi^+$  modes, the corresponding numbers are 0.91, 0.96, and 0.96. The error in this fit bias due to MC statistics is included as a systematic uncertainty. These MC studies also indicate that correlations between the  $B$  background and the continuum background fit yields do not affect the fitted signal yield.

The projections of the maximum likelihood fits on  $m_{ES}$  and  $\Delta E^*$  are shown in Fig. 1 for each decay mode. Figure 2 shows that the background-subtracted  $K\pi$  invari-

TABLE II: Fractional systematic uncertainties on the branching fractions  $\mathcal{B}$  and absolute systematic uncertainties on CP asymmetry  $\mathcal{A}$ .

| Description                     | Systematic errors on $\mathcal{B}$ (%) |              |            |              |
|---------------------------------|----------------------------------------|--------------|------------|--------------|
|                                 | $K^+\pi^-$                             | $K_s^0\pi^0$ | $K^+\pi^0$ | $K_s^0\pi^+$ |
| Number of $B$ events            | 1.1                                    | 1.1          | 1.1        | 1.1          |
| $R^{+/0}$                       | 2.4                                    | 2.4          | 2.4        | 2.4          |
| Tracking efficiency             | 1.6                                    |              | 0.8        | 0.8          |
| Charged particle identification | 1.0                                    |              | 1.0        | 1.0          |
| Photon efficiency               | 2.5                                    | 7.6          | 7.6        | 2.5          |
| Photon isolation cut            | 2.0                                    | 2.0          | 2.0        | 2.0          |
| $\pi^0, \eta$ veto              | 1.0                                    | 1.0          | 1.0        | 1.0          |
| $K_s$ efficiency                |                                        | 3.0          |            | 3.0          |
| Neural network                  | 3.0                                    | 3.5          | 2.7        | 2.8          |
| PDF parameterization            | 2.2                                    | 7.3          | 2.7        | 1.4          |
| MC statistics/fit bias          | 0.9                                    | 3.2          | 2.4        | 1.6          |
| Total                           | 5.8                                    | 12.3         | 9.4        | 6.3          |
| Description                     | Systematic errors on $\mathcal{A}$ (%) |              |            |              |
|                                 | $K^+\pi^-$                             | $K_s^0\pi^0$ | $K^+\pi^0$ | $K_s^0\pi^+$ |
| Tracking efficiency             | 0.35                                   |              | 0.25       | 0.25         |
| Charged particle identification | 1.00                                   |              | 0.55       | 0.53         |
| Nuclear interaction asymmetry   | 0.20                                   |              | 0.35       | 0.15         |
| $B$ -background asymmetry       | 0.25                                   |              | 0.25       | 0.25         |
| Total                           | 1.1                                    |              | 0.7        | 0.7          |

ant mass distributions agree well with the expected  $K^*$  resonance shape. This confirms that the signal is consistent with coming from only true  $K^*$  decays.

Table shows signal efficiencies, yields from the fits, and branching fractions ( $\mathcal{B}$ ) calculated using our recent measurement [17] of the production ratio of charged and neutral  $B$  events,  $R^{+/0} \equiv \Gamma(e^+e^- \rightarrow B^+B^-)/\Gamma(e^+e^- \rightarrow B^0\bar{B}^0) = 1.006 \pm 0.048$  at  $\sqrt{s} = M_{\Upsilon(4S)}$ .

Combined values of  $\mathcal{B}(B^0 \rightarrow K^{*0}\gamma)$  and  $\mathcal{B}(B^+ \rightarrow K^{*+}\gamma)$ , which are also shown in Table , are calculated taking into account correlated systematic errors between modes. We further combined these measurements, using the lifetime ratio  $\tau_{B^+}/\tau_{B^0} = 1.083 \pm 0.017$  [13] and our measurement of  $R^{+/0}$ , to find the isospin asymmetry,  $\Delta_{0-} = 0.050 \pm 0.045(\text{stat.}) \pm 0.028(\text{syst.}) \pm 0.024(R^{+/0})$ , which corresponds to an allowed region of  $-0.046 < \Delta_{0-} < 0.146$  at the 90% confidence level. We also present a combined  $\mathcal{A}$  measurement in Table , which corresponds to an allowed region of  $-0.074 < \mathcal{A}(B \rightarrow K^*\gamma) < 0.049$  at the 90% confidence level.

The systematic error on the branching fraction for each mode is shown in Table II. Most of the uncertainties are determined as in our previous analysis [6], so we provide details only for the new procedures used. The neural-network inputs are generally independent of the fully reconstructed  $B \rightarrow K^*\gamma$  candidate, so we determine their efficiencies and systematic uncertainties with high-purity control samples with reconstructed  $B^- \rightarrow D^0\pi^-$  and  $B^0 \rightarrow D^-\pi^+$ . The “PDF parameterization” error comes from MC studies of our fitting procedure, in which we estimate the uncertainty incurred by fixing param-

ters in the continuum and  $B$  background models. This includes uncertainty in the inclusive branching fraction and spectral shape of  $B \rightarrow X_s \gamma$ .

The systematic uncertainties in the measurement of  $\mathcal{A}$  are also shown in Table II. The first three contributions arise from potential particle-antiparticle asymmetries in the detector response, including differences in interaction cross-sections for  $K^+$  and  $K^-$ , and for  $\pi^+$  and  $\pi^-$  (estimated with a method similar to that used in Ref. [18]). The uncertainty due to a possible asymmetry in the  $B$  background, which is dominated by  $B \rightarrow X_s \gamma$ , is estimated by varying our recent measurement of  $\mathcal{A}(B \rightarrow X_s \gamma)$  [19] within its errors.

We conclude that both the isospin- and CP-asymmetries in  $B \rightarrow K^* \gamma$  decay processes are consistent with SM predictions. The branching fractions measured are also consistent with SM-based calculations and are more precise than those predictions. These measurements are consistent with previous results [5, 6, 7].

We are grateful for the excellent luminosity and machine conditions provided by our PEP-II colleagues, and for the substantial dedicated effort from the computing organizations that support BABAR. The collaborating institutions wish to thank SLAC for its support and kind hospitality. This work is supported by DOE and NSF (USA), NSERC (Canada), IHEP (China), CEA and CNRS-IN2P3 (France), BMBF and DFG (Germany), INFN (Italy), FOM (The Netherlands), NFR (Norway), MIST (Russia), and PPARC (United Kingdom). Individuals have received support from CONACyT (Mexico), A. P. Sloan Foundation, Research Corporation, and Alexander von Humboldt Foundation.

---

\* Now at Department of Physics, University of Warwick, Coventry, United Kingdom

† Also with Università della Basilicata, Potenza, Italy

‡ Also with IFIC, Instituto de Física Corpuscular, CSIC-Universidad de Valencia, Valencia, Spain

§ Deceased

- [1] K. Lingel, T. Skwarnicki, and J. Smith, *Ann. Rev. Nucl. Part. Sci.* **48**, 253 (1998).
- [2] M. Beneke, T. Feldmann, and D. Seidel, *Nucl. Phys.* **B612**, 25 (2001), hep-ph/0106067.
- [3] S. W. Bosch and G. Buchalla, *Nucl. Phys.* **B621**, 459 (2002), hep-ph/0106081.
- [4] A. Ali and A. Y. Parkhomenko, *Eur. Phys. J.* **C23**, 89 (2002), hep-ph/0105302.
- [5] CLEO Collaboration, T. E. Coan *et al.*, *Phys. Rev. Lett.* **84**, 5283 (2000), hep-ex/9912057.
- [6] BABAR Collaboration, B. Aubert *et al.*, *Phys. Rev. Lett.* **88**, 101805 (2002), hep-ex/0110065.
- [7] Belle Collaboration, M. Nakao, submitted to *Phys. Rev. D* (2004), hep-ex/0402042.
- [8] UKQCD Collaboration, L. Del Debbio, J. M. Flynn, L. Lellouch, and J. Nieves, *Phys. Lett.* **B416**, 392 (1998), hep-lat/9708008.
- [9] P. Ball and V. M. Braun, *Phys. Rev.* **D58**, 094016 (1998), hep-ph/9805422.
- [10] A. L. Kagan and M. Neubert, *Phys. Lett.* **B539**, 227 (2002), hep-ph/0110078.
- [11] A. L. Kagan and M. Neubert, *Phys. Rev.* **D58**, 094012 (1998), hep-ph/9803368.
- [12] BABAR Collaboration, B. Aubert *et al.*, *Nucl. Instrum. Meth.* **A479**, 1 (2002), hep-ex/0105044.
- [13] PDG Collaboration, K. Hagiwara *et al.*, *Physical Review D* **66**, 010001 (2002).
- [14] ARGUS, H. Albrecht *et al.*, *Z. Phys.* **C48**, 543 (1990).
- [15] The Novosibirsk function is defined as  $f(m_{ES}) = A_S \exp(-0.5\{\ln^2[1 + \Lambda\tau \cdot (m_{ES} - m_0)]/\tau^2 + \tau^2\})$ , where  $\Lambda = \sinh(\tau\sqrt{\ln 4})/(\sigma\tau\sqrt{\ln 4})$ , the peak position is  $m_0$ , the width is  $\sigma$ , and  $\tau$  is the tail parameter.
- [16] E. Bloom and C. Peck, *Ann. Rev. Nucl. Part. Sci.* **33**, 143 (1983).
- [17] BABAR Collaboration, B. Aubert *et al.*, *Phys. Rev.* **D69**, 071101 (2004), hep-ex/0401028.
- [18] BABAR Collaboration, B. Aubert *et al.*, submitted to *Phys. Rev. Lett.* (2004), hep-ex/0401035.
- [19] BABAR Collaboration, B. Aubert *et al.*, submitted to *Phys. Rev. Lett.* (2004), hep-ex/0403035.